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AN/FO CHARGE PREPARATION FOR LARGE SCALE TESTS

By
L. D. Sadwin
M. M. Swisdak, Jr.

8 OCTOBER 1970

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND 20910

NOLTR 70-205

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AN/FO CHARGE PREPARATION FOR LARGE SCALE TESTS

Prepared by:
L. D. Sadwin and M. M. Swisdak, Jr.

ABSTRACT: Two 20- ton and one 100-ton hemispherical AN/FO charges were detonated on the surface at the Defence Research Establishment, Suffield, Ralston, Alberta, Canada. The charges were all prepared with on-site mixing of the AN/FO over a 15 day period during August 1969. The first 20-ton charge was prepared from 800 fifty pound bags of AN/FO stacked in a hemispherical pile. The remaining charges were formed in thin hemispherical fiberglas shells. Each charge was initiated by a 250-pound booster.

AN/FO has been demonstrated to be a highly suitable explosion source for simulation of nuclear airblast.

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Air/Ground Explosions Division
Explosions Research Department
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

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AN/FO Charge Preparation for Large Scale Tests

This report describes the explosives engineering aspects of the 20- and 100-ton AN/FO trials conducted during August 1969, in cooperation with the Canadian Defence Research Establishment, Suffield at Ralston, Alberta, Canada. The report can serve as a guide for others interested in preparing AN/FO charges for nuclear blast simulation purposes.

This effort was funded by the Defense Atomic Support Agency through the Naval Ship Systems Command. The work was performed under DASA Subtask NA 007-04, Task NOL-194, "AN/FO Feasibility Study".
The AN/FO system is being developed as an inexpensive substitute for TNT for large scale nuclear airblast simulation trials.

Company and trade names are used throughout the report for technical information purposes only. No endorsement or criticism is intended.

GEORGE G. BALL
Captain, USN
Commander

C. J. ARONSON
By direction

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1. INTRODUCTION

1.1 BACKGROUND. There is a continuing requirement for an economical, large scale airblast source capable of simulating the blast environment of a nuclear explosion. The Navy, for example, exposes special structures and fully operational ships to large blasts in its program to blast-harden ships.

During 1967, in an effort to find an economical blast source for large scale operational use, NOL proposed that AN/FO, a commercial blasting agent, be considered for applications requiring as much as 500 tons or more of high explosive. AN/FO is prepared by mixing fertilizer grade ammonium nitrate with No. 2 diesel fuel in a 94 to 6 weight ratio.

The first phase of the effort to establish the applicability of AN/FO for target response tests was conducted in Nevada during 1968. The feasibility of AN/FO as an explosive source for the proposed application was demonstrated. Blast measurements were obtained in the pressure range from 40 to 1 psi for charges weighing 260 to 4,090 pounds. The data from this initial program indicated that AN/FO has peak pressure-distance characteristics very close to those of TNT (Ref. (1))*. Larger scale demonstration tests were now needed to verify the scaling relationships and to study operational aspects of large AN/FO detonations.

This report documents the explosive placement operation for the Phase II AN/FO effort where two 20-ton and one 100-ton hemispherical charges were detonated. Another NOL report has been issued which publishes the airblast and other data obtained by NOL during these tests (Ref. (2)).

1.2 AN/FO TRIALS OF AUGUST 1969. The Phase II tests were conducted as a joint U. S./Canadian effort in cooperation with the Defence Research Establishment, Suffield at Ralston, Alberta, Canada. The schedule of the three tests conducted during the AN/FO trials at DRES was as follows:

a. Event I - 20-ton AN/FO hemisphere, bagged. Detonated at 1100 MST on 14 August 1969.

* References are listed on page 13.

b. Event II - 20-ton AN/FO hemisphere, bulk in fiberglas shell. Detonated at 1100 MST on 21 August 1969.

c. Event III - 100 ton AN/FO hemisphere, bulk in fiberglas shell. Detonated at 1100 MST on 28 August 1969.

2. PROPERTIES OF AN/FO

2.1 AMMONIUM NITRATE (AN) AND ITS USE IN AN/FO. Ammonium nitrate, NH_4NO_3, is a very stable chemical compound. Its major use is as an industrial fertilizer; its secondary use is in mining explosives. Ammonium nitrate is produced in large quantities--the projected 1969 production of AN in the U. S. was over 6 million tons (Ref. (3)). Of this total, 10% was intended for use in explosives. Reference (4) gives a brief description and history of the use of AN in conventional explosives.

About the time of World War II the prilling process for solidification of AN was begun on a commercial scale. Prilling is a procedure whereby a concentrated solution of AN is sprayed from the top of a 150-to 180-foot tower, solidification taking place as the AN falls to the bottom. Prills are small, spherical, somewhat porous particles much like lead shot in size and shape (Fig. 1). The density of an individual AN prill is about 1.4 gm/cc compared to a crystal density of 1.725 gm/cc. The bulk density of prilled AN is about 0.8 to 0.85 gm/cc.

With the advent of the prilling process, a new class of blasting agents became available. Industrial users of explosives were very quick to investigate how to use AN-based explosives (consisting primarily of AN and a carbonaceous fuel) because of their low cost (about 5¢ per pound) compared to the dynamites. It was found that if the AN prill was made sufficiently porous it could hold enough fuel oil (FO) to make a stoichiometric mixture of AN and FO which had excellent explosive characteristics. This mixture has become known throughout the mining industry as AN/FO and it has gained wide use in commercial blasting and seismic applications.

The process used in the manufacture of the AN is described in Figure 2. In this Figure we have reproduced the flow chart that is

distributed by Cominco Ltd. of Calgary, Alberta. Cominco is one of the first manufacturers to produce prilled AN on a commercial scale. Their original prilling tower is still in use. The explosives contractor[1] on these AN/FO trials used AN manufactured by Cominco. The physical properties of this AN are presented in Table 1.

Although commercial fertilizer grade AN was used in the tests, there are many differences in the characteristics of the AN within this grade. AN prepared specifically for use in explosives should be used. In particular, the use of a porous prill and the presence of a surfactant coating (Ref. (5)), such as Petro-AG, to promote easy distribution of the fuel oil in the AN is desired. In addition, the bulk density of the mixed product should be in the vicinity of 0.85 to 0.90 grams/cc for satisfactory handling and detonation behavior. In this program, we did not experimentally explore all the varieties of AN manufactured for blasting use; we selected one that promised to be satisfactory, and it was.

AN is hygroscopic and must be protected against water and high humidity conditions. The presence of a few percent by weight of water in AN/FO has a deleterious effect on its detonation and explosion performance (Ref. (6)). Bagged AN is usually protected against moisture by a polyethylene layer in the multiwall paper bags used. Large quantities of exposed AN or AN/FO sometimes form a caked layer on the outside surface; this caking prevents further penetration of the nondesirable moisture.

Fortunately for our requirement, the commercial explosives companies have developed bulk handling and mixing equipments for delivery and placement of large quantities of AN/FO. One advantage of the AN/FO system is that each component can be transported commercially as nonexplosive material with the mixing operation being done on site. This technique lends itself well to the type of operation contemplated for large scale explosion trials.

The AN used during these AN/FO trials was transported from Calgary in two ways: (a) Railhopper car and (b) Tanker truck.

---

[1] Ace Explosives Ltd. of Calgary, Alberta was the [illegible] contractor at DRES during August 1969.

The first shipment of AN was in the form of a 70-ton railroad hopper car. Figure 3 is a photograph showing, on the extreme right, the AN hopper car at the Suffield, Alberta RR siding. This photograph shows the AN being fed from the hopper car into the bins of the mixer truck. The mixer truck had a capacity of about 7 tons of AN.

As seen in Figure 4, the railroad was located 35 miles from the blast range. After the first loading of the mixer truck at the railroad siding, it became evident that an inordinately long time must be spent in traveling the 35 miles to the blast range. In order to reduce this transportation time, the remainder of the AN was transported directly to the blast site in 22-ton capacity Trimac tanker trucks. The tanker trucks were equipped with a pneumatic feed system which pumped the AN directly into the bins of the AN/FO mixer truck stationed at the blast site.

2.2 FUEL OIL (FO). The fuel oil used in the 94/6 AN/FO was commercially available No. 2 diesel fuel. The properties of this fuel are given in Table 2.

A red dye (DuPont Oil Red) was added to the FO at the rate of 12.5 ounces of dye to 100 U. S. gallons fuel oil. This gave the mixed AN/FO a pink color. The red dye enabled making quick visual checks of the AN/FO for uniformity in fuel oil content. The properties of this liquid dye are presented in Table 3.

2.3 AN/FO MIXING AND HANDLING. The mixer truck flow diagram in Figure 5 illustrates in a schematic way how the AN is fed from the bins along a horizontal auger to the place where the fuel oil is sprayed into the moving AN. From this point, the mixed AN/FO is moved by a vertical auger to the swinging auger and out into the container or other receptacles. Note that, in contrast to the safety restrictions placed upon conventional high explosives, AN/FO is routinely handled with an auger system.

In addition to the visual check on the fuel oil content of the mixed AN/FO (by observing the constancy of the pink color), the fuel oil content was monitored periodically by chemical analysis during the loading of each charge. The analysis procedure is quite simple and was designed for ease in making quick checks in the field. The procedure is described in Table 4.

Each truckload of AN plus FO was weighed by use of portable truck scales (Fig. 6), with the weight noted for the truck empty and loaded. The weight obtained in this way was checked against the total weight of the 20-ton bagging operation (see Sec. 3.2) and the agreement was excellent.

3. CHARGE DESIGN, CONSTRUCTION, AND PERFORMANCE

3.1 TNT BOOSTER AND PRIMACORD INITIATION METHOD

The hemispherical boosters used for all three events were prepared by the U. S. Naval Ammunition Depot, Hawthorne, Nevada, (Ref. (7)). The boosters were a nominal 250 pounds each total weight and consisted of a 16-pound hemispherical 50/50 pentolite primer with about 234 pounds of TNT cast over it.

NOL developed a primacord initiation method (Ref. (1)) which was used for booster initiation on each event. In this method, a strand of 100 grains per foot primacord is placed in a shallow, radial trench beneath the charge, leading from beyond the outer edge of the AN/FO charge to the ground zero (GZ). The GZ end of the primacord is fed through a radial hole in the booster, and a small knot is tied at the top to secure it. This method greatly simplifies the arming procedure, as the electric detonator is simply attached to the other end of the primacord still exposed after the charge has been completed. The explosive train is: electric detonator ⟶ primacord ⟶ pentolite primer ⟶ TNT booster ⟶ main charge (AN/FO); this is illustrated schematically in Figure 7. The booster arrangement for Event I, specifically, but similarly for Events II and III, is shown in Figure 8.

3.2 EVENT I DESIGN

Event I was a 20-ton hemispherical charge constructed of bagged AN/FO. The bags, when filled, had a capacity of 50-pounds of AN/FO, and had dimensions of 21 x 13.5 x 5.8 inches. The bags were multiwall with a rough paper outer layer and a polyethylene inner layer. They were self-closing, valve-type bags. Each empty bag had a nominal weight of 0.53 pounds.

The AN/FO was mixed and bagged at ground zero. The AN/FO was fed from the mixing truck into two hoppers located within a

bagging unit. The flow from these hoppers into the bags was controlled by electric valves; the length of time that the valves remained open determining the amount of AN/FO placed in each bag. A random check of filled bags throughout the bagging operation indicated that their weight was 50 ± 0.1 lb. The filled bags were then placed on a short conveyer belt leading out of the bagging unit. The layout of the mixer and bagging unit is shown in Figure 9. The total weight of AN/FO placed into the bagging unit hoppers was also monitored by the truck scales shown in Figure 6.

A 20-ton AN/FO hemisphere is 7.1 feet in radius for an AN/FO density of 53 lb/ft^3 (0.85 gm/cc). Assuming a nominal filled bag thickness of 5.8 inches, 15 layers of bags can be stacked within the 7.1 feet radius. The total number of bags to be placed in each layer was computed by calculating the volume of that layer. The first eleven layers were designed with circumferential rings of bags. The interior of each layer was filled with a predetermined pattern of bags. Loose AN/FO from the bags which could not fit into this pattern but which were required to complete the total weight for each layer was used to fill the spaces between the bags in the pattern. The addition of the loose AN/FO had a more important role than just getting the charge up to weight; it helped create a homogeneous charge structure with no large air spaces within the charge. Except for the bagging material, the charge was uniformly explosive material with no voids, discrepancies in density, or other nonuniformities commonly found in large, block built TNT charges.

On layers 12-15 a predetermined pattern of bags without a circumferential ring was used. Again, loose AN/FO was used to fill in the spaces between the bags. The planning information for each layer is presented in Table 5. The design arrangement or pattern of bags in each layer is shown in Figures 10 to 23. In most cases the pattern was followed as computed. Occasionally, during the construction of the charge, there were modifications of the exact design, but the number of bags was not changed. For example, this is illustrated for the case of layer 2 in Figure 24. Figures 24, 25, and 26 show layers 2, 10, and the completed charge for Event I.

The characteristics of the completed Event I charge are presented in Table 6.

3.3 EVENTS II AND III DESIGN. In the early stages of the design of the hemispherical containers for these AN/FO trials, nylon fabric was the prime material considered. It offered the advantages of being nonfragmenting, consumable, and having sufficient strength for this application. The reason for rejecting it as a candidate material was its high cost (the containers would cost more than all of the AN/FO required in the test program); also after some scaled tests on hemispherical models of nylon fabric, several severe problems were noted. Among these were the tendency of the filled nylon hemisphere to approach an oblate spheriod in shape, the characteristic of the nylon to continuously stretch under load, and the observation that the filled envelope developed a decided and not easily controlled list.

A stiffer and lower cost material was needed and a fiberglas /polyester resin laminate was selected. This material offered all of the advantages of the nylon and would hold up better under the rough handling anticipated in the field. The stiffness of the laminate made the container self-supporting, thus simplifying the explosive fill operation.

A number of preliminary tests were conducted on the proposed fiberglas /polyester resin material. Tensile tests were run on 3/16-inch thick samples. As the hemispherical container would be made up of individual gore-like sections, tensile tests also were run in order to select the adhesive system to be used in joining the various sections together.

The hoop stress at the base of the container was considered the controlling factor in establishing the container strength. Assuming that the AN/FO would behave like a liquid and that the container is analogous to a pressurized sphere, a conservative estimate for the hoop stress is readily calculated by the following formula (Ref. (8)).

$$S_{Hoop} = \frac{PR}{2t} \tag{1}$$

where S_{Hoop} is the hoop stress in psi, P is the hydrostatic pressure in psi, R is the container radius in inches, and t is the container thickness in inches (t = .19 inches on Event II and .25 inches on Event III).

The hydrostatic pressure, obtained by assuming the AN/FO behaves as a liquid, is calculated by the formula

$$P = \gamma H, \tag{2}$$

where γ is the AN/FO density in pounds per cubic inch and H is the maximum AN/FO height in inches.

Using Equations (1) and (2), the hoop stresses as calculated for the containers of Events II and III are 563 psi and 1320 psi.

As can be seen in the test data summarized in Table 7, the tensile strength of the fiberglas/polyester laminate itself is far stronger than is required to sustain the hoop stresses. Therefore, the lap joints between the sections must be designed to withstand these stresses. For a joint with a 3-inch wide overlap (as was the case for the containers on Events II and III) the shear stresses corresponding to the above hoop stresses are 36 and 110 psi. Tensile tests on various adhesive-bonded lap joints are also summarized in Table 7.

The above hoop stress calculations are very conservative estimates; they serve to give upper bound estimates of the actual stresses involved. Although the Epon 828, V-35, DMP-30 adhesive system would have been the best to use for the lap joints, several factors forced us to use the HYSOL C-A571 adhesive system. This lap joint-adhesive system provided a safety factor of about 5 for the Event III container.

High speed camera tests on explosively loaded, disc-shaped samples of the laminate material were run to study how the container material would break up during the trials. The experimental arrangement used is shown in Figure 27. A sequence of frames taken on one of the tests is presented in Figure 28. Note that within about an inch and a half, there is an increase in luminosity of the moving fiberglas sample. This is interpreted as burning of the

polyester resin in the sample. No integral pieces of the sample were found after these tests, nor were there any pieces observed after Events II and III carried out at DRES.

The container[1] for Event II was 14.0 feet in base diameter and consisted of eleven individual sections having full compound spherical curvature. Similarly, the container for Event III was 24.2 feet in base diameter and had twenty-two sections.

Each container had a large circular opening at the top to permit easy filling. The diameter of the opening was 7 feet on the Event II container and 14 feet on the Event III container. These openings also provided a way for personnel to enter the containers to place the 250-pound TNT boosters and to help distribute the AN/FO within the shell. The containers had sufficient structural strength, even when empty, to support ladders and personnel.

In addition to the adhesive applied between each joint, nylon bolts were also used in the overlap regions. These served a dual purpose. The bolts provided some shear load carrying capacity; they also held the adjoining sections of the container together until the adhesive cured. The nylon bolts were found too weak to hold the lap joints together on the Event III container. Steel bolts were used until the adhesive cured (about 36 hours) and then all the steel bolts were replaced with nylon ones in order to eliminate the possibility of steel fragments.

The physical characteristics of the charges for all three events are presented in Table 6.

The fully prepared AN/FO charges for Events II and III are shown in Figures 29 and 30 respectively. In order to attain the full hemispherical shape desired for the charges, after the containers were filled, they were topped with unconfined AN FO and smoothed to the proper contour. On the day before firing, a few of the lap joints on the Event III container were thought to be yielding. As a precaution, several manila ropes were tied around the container near the base. The ropes were removed several hours before detonation time when it was determined that no yielding had taken place as

[1] The containers were manufactured by Rogay Models of Bethesda, Maryland

evidenced by the fact that the ropes had not tightened overnight. Figure 30 was taken shortly before the ropes were removed.

The internal dimensions of the containers were measured after placement at ground zero, but prior to the beginning of the filling operations. On Event II, the radius of each section was found to be nearly constant at 7.0 feet. On Event III, some distortion of the container was noted. Radius measurements were made at four points along each section--at the base of the section, 3.83 feet up along the seam, 7.42 feet along the seam, and at the top of the section. These measurements are contained in Table 8.

The volume of the Event III charge (both container and assumed hemispherical cap on top) was determined by using the theorem of Pappus (Ref. (9)). The total volume of the container and cap was found to be 3,724 ft^3. The Event II charge had a volume of 718 ft^3.

3.4 CHARGE PERFORMANCE

The detonation velocity of the AN/FO was not directly measured. However, detonation velocity can be inferred from other observations made on each of the three AN/FO tests. From the ionization probe and time of arrival data obtained by DRES, as published in Ref. (10)) the estimated detonation velocities of the AN/FO were as follows:

Event I	4,570 meters/sec
Event II	4,250 meters/sec
Event III	4,600 meters/sec

These estimated velocities indicate that the AN/FO detonated within a few percent of its ideal detonation velocity on all three trials.

4. CONCLUSIONS

The ability to adhere to the relatively rigid schedule set up for these AN/FO trials is testimony to both the suitability of the AN/FO system to large scale nuclear blast simulation and to the cooperative field effort between all U. S. and Canadian agencies participating in the AN/FO trials of August 1969.

The three events, totaling 140 tons of AN/FO were prepared for firing over a 15-day time period. Relative to large, block built TNT charge preparations, few personnel were required for the AN/FO charge preparations. The bagged charge for Event I was prepared by 9 men working a total of 54 man-hours. The container for Event II required 5 people working a total of 40 man-hours to assemble. Once assembled, the Event II container required 5 people working 45 man-hours to be filled with AN/FO. The Event III container required 8 people working 64 man-hours for assembly. Once the container was completed, it required 5 people working a total of 78 man-hours to be filled with explosive. The explosive supplier used a three man crew and their time is included in the above figures. Except for a few mechanical difficulties with the mixing equipment, the operation went very smoothly. No problems are foreseen for future larger operations which may be planned. In fact, for future large scale operations where 500 tons or more of AN/FO are to be prepared, multiple delivery and mixing systems can be used to reduce charge preparation time if this is of importance to the program.

The economy of bagged charges over those placed in containers was clearly demonstrated. Although the base cost of the bagged AN/FO runs about 15% higher than for bulk AN/FO, the actual inplace cost (including labor) for Event I was less than for Events II and III (7.7¢/pound compared to 17.7¢/pound and 9.3¢/pound). The high per pound cost of Event II was primarily due to the cost of the container. In fact the container cost for Event II exceeded that of the explosive.

The inherent safety of the AN/FO system was also amply demonstrated during this program.

Acknowledgements

We wish to acknowledge the following individuals who contributed to the success of this effort: N. L. Coleburn for the high speed photographic tests on the explosive loading of fiberglas, D. S. Lequin for the strength tests on fiberglas samples, G. R. Rintoul of Ace Explosives, Ltd and C. M. Myers of the Defence Research Establishment, Suffield, for the smoothness of the explosives placement operation, and T. J. Haynes of Rogay Models for design and fabrication of the fiberglas/polyester resin laminate containers.

In addition to the authors, the following NOL personnel participated in this AN/FO field program: Maurice Brooks, Roy W. Huff, Christopher Johnson, Richard L. Knodle, Gruver H. Martin, and Edwin G. Nacke. Joseph Petes served as adviser.

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Table 1

PROPERTIES OF THE AMMONIUM NITRATE
USED IN THE AN/FO TRIALS AT DRES, AUGUST 1969

DETAILED DESCRIPTION OF NITRAPRILLS S

Description of Product

A free running product consisting of the chemical ammonium-nitrate in a prilled form conditioned against caking by the addition of Barnette Clay, and containing a Surfactant Petro-AG.

Color: White to cream.

Bulk Density: lb per cu ft-48 poured, 52 packed.

Angle of Repose: 33°

Packaging

Packed in multiwall paper bags with valve-type closure or in bulk carload lots.

Detailed Chemical Analysis of Typical Samples Taken on AN/FO Trials

	Shipment Aug 7/69 Rail Car CP387114 Order No. CC105	TRUCK SHIPMENTS Aug 23/69 CC159-1	Aug 25/69 CC159-2	Aug 26/69 CC171
% Total Nitrogen (N)	34.7	34.7	34.7	34.6
% H_2O	0.16	0.06	0.07	0.10
% Conditioner	0.8	0.8	0.7	0.9
% +14 Tyler Mesh Screen Analysis	95.8	94.5	95.6	94.6

Table 2

TYPICAL INSPECTION OF ESSO NO. 2 DIESEL FUEL
(SUMMER GRADE) 1969

Gravity, °API	36.0
Flash Point, °F	140
Kinematic Viscosity @100°F, centistokes	2.70
Cloud/Pour Point, °F.	+6/0
Sulfur and Water, %	NIL
Cetane No., calculated.	46.0
Initial Boiling Point, °F	320
50%	470
Final Boiling Point, °F	676

Table 3

PROPERTIES OF DUPONT OIL RED B LIQUID

DuPont Oil Red B Liquid is an oil soluble dye for gasoline and other petroleum products. It is a solution of dye in xylene.

TYPICAL PHYSICAL PROPERTIES

Physical Appearance	Dark red liquid
Visual Strength, Hellige, %	45*
Pour Point, °F	Below -20
Specific Gravity at 60°F	1.01
Pounds/Gallon at 68°F	8.4

Viscosity:

Temperature, °F	Kinematic, cs
32	660
77	88
100	39

Flash Point Tag Open Cup, °F	96

Soluble in petroleum fractions in all proportions.

* Based on Oil Red A Powder or Flakes

Table 4

TEST METHOD USED TO DETERMINE AMOUNT OF NO. 2 DIESEL FUEL IN AN/FO MIXTURE

EQUIPMENT:

1 - Balance Scale

3 - Beakers

3 - Sintar Crucibles

METHOD:

1. Weigh beaker and record weight. Add 20 grams of AN/FO mixture and record weight.

2. Pour Petroleum Ether over AN/FO mixture in beaker and decant--do this three times.

3. Pour material in Sintar Crucible and allow to dry for 1½ hours.

4. Pour material into beaker and weight--record weight.

5. Deduct weight of beaker and record.

6. If using 6% fuel oil, the weight removed should be 1.20 grams for 20.00 grams of AN/FO.

Table 5

DESIGN INFORMATION FOR EVENT I CHARGE CONSTRUCTION

Layer No.	Layer Radius (ft)	No. of Bags in Outer Ring	No. of Bags in Central Pattern	No. of Bags Bulk	Total No. of Bags
1	7.11	23	40	17	80
2	7.08	23	40	17	80
3	7.02	23	40	16	79
4	6.92	22	40	15	77
5	6.78	22	40	12	74
6	6.62	22	36	12	70
7	6.40	21	32	12	65
8	6.15	20	32	8	60
9	5.83	19	26	10	55
10	5.47	17	20	9	46
11	5.02	16	18	6	40
12	4.50	--	26	6	32
13	3.83	--	20	4	24
14	2.95	--	10	4	14
15	1.51	--	2	2	4
	TOTAL	228	422	150	800

Table 6

AN/FO CHARGE CHARACTERISTICS

	Event I	Event II	Event III
Base Diameter - Ft	14.2	14.0	24.2
Container Thickness - Inches	--	.19	.25
Weight of AN/FO - Pounds	39,920	37,350	200,650
Weight of Booster - Pounds	250	250	250
Total Weight - Pounds	40,170	37,600	200,900
AN/FO Density - gm/cc	.88[1]	.839	.865
Fuel Oil - %	5.85	5.90	5.95

1. Estimate--volume not controlled for this bagged construction.

Table 7

TENSILE AND ADHESIVE SHEAR TEST RESULTS ON FIBERGLAS/POLYESTER RESIN LAMINATES

Tensile strength of fiberglas/polyester resin laminate: 25,900 psi.

Adhesive shear strength test results after 48 hours at 71°F and 50% R.H.

Adhesive Type	Overlap Inches	Average shear strength PSI
EPON 828, V-25, DMP-30	1 x 1/2	1280
EPIBOND 123	1 x 1/2	280
HYSOL C-A571	1 x 1/2	893
HYSOL C-A571	1 x 3	568

Table 8

DIMENSIONS OF EVENT III CONTAINER (PRIOR TO FILLING)

RADIUS IN FEET

Seam	Base	3.83 Ft*	7.42 Ft*	Top
1-2	12.2	12.4	12.4	11.85
3-4	12.1	12.4	12.4	11.85
5-6	12.1	12.35	12.4	11.8
7-8	12.1	12.35	12.45	11.8
9-10	12.15	12.4	12.45	11.75
11-12	12.1	12.4	12.45	11.8
13-14	12.05	12.4	12.4	11.85
15-16	12.1	12.4	12.4	11.85
17-18	12.15	12.45	12.4	11.85
19-20	12.3	12.5	12.45	11.85
21-22	12.3	12.5	12.45	11.85
23-24	12.2	12.5	12.5	11.9
25-26	12.2	12.5	12.5	11.9
27-28	12.15	12.45	12.5	11.9
29-30	12.1	12.4	12.45	11.85
31-32	12.1	12.4	12.45	11.85
33-34	12.1	12.4	12.4	11.8
35-36	12.0	12.35	12.4	11.7
37-38	12.1	12.4	12.4	11.7
39-40	12.2	12.45	12.4	11.75
41-42	12.3	12.4	12.45	11.75
43-44	12.2	12.4	12.45	11.75

* Measured along the seam

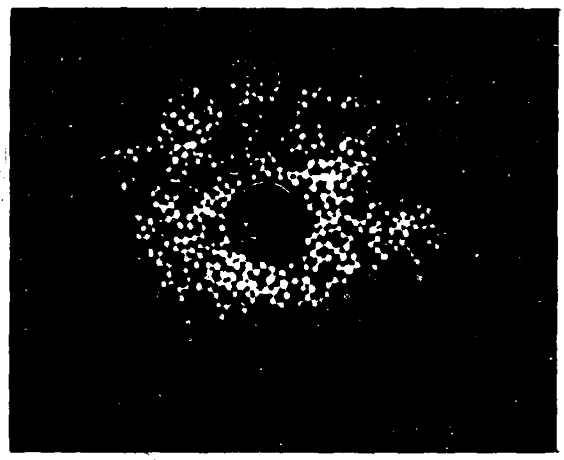


FIG. 1 PHOTOGRAPH OF SOME REPRESENTATIVE AMMONIUM NITRATE PRILLS

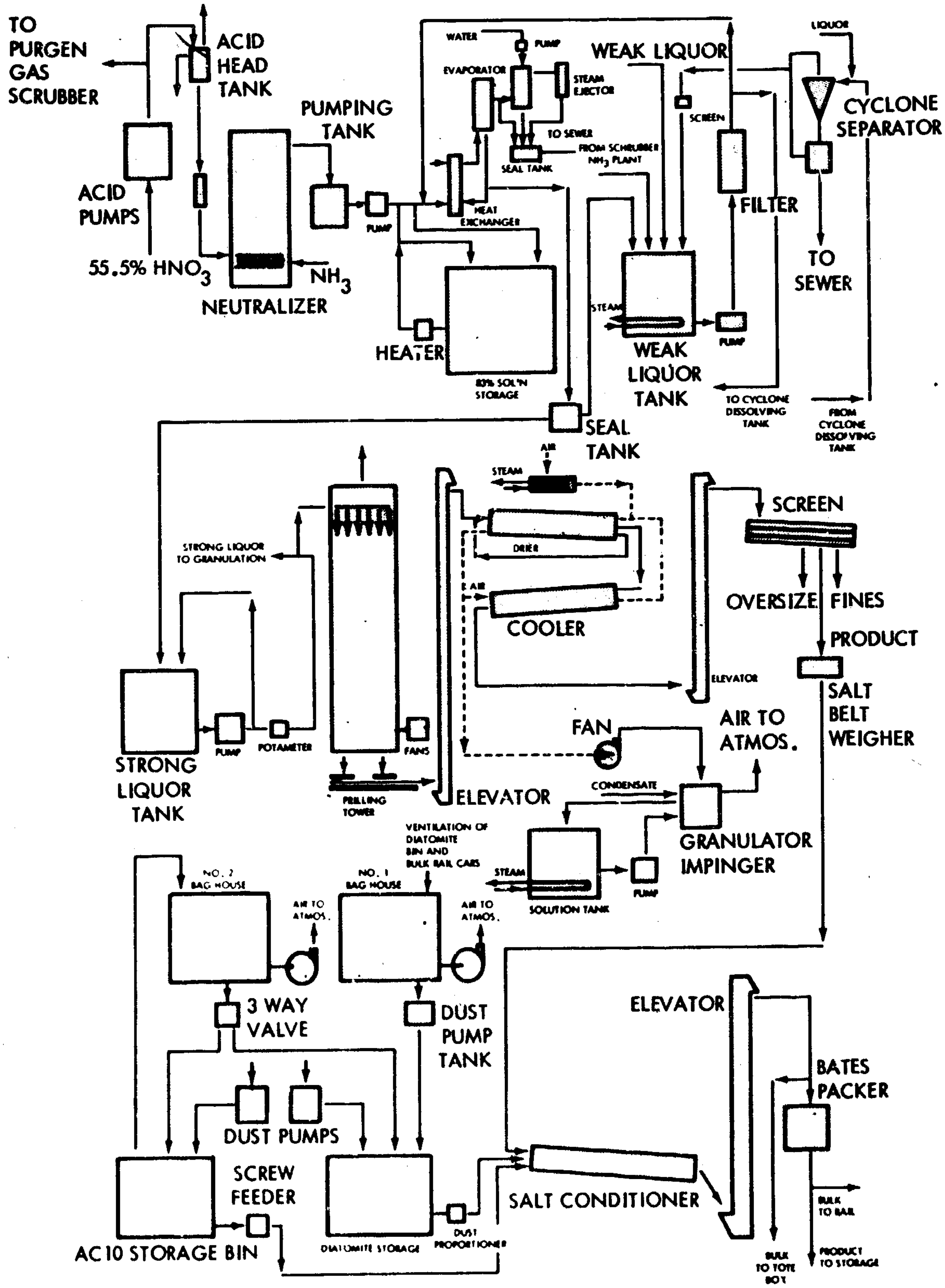


FIG. 2 SIMPLIFIED FLOWSHEET OF AMMONIUM NITRATE PRILLING PROCESS USED BY COMINCO, LTD OF CALGARY, ALBERTA.

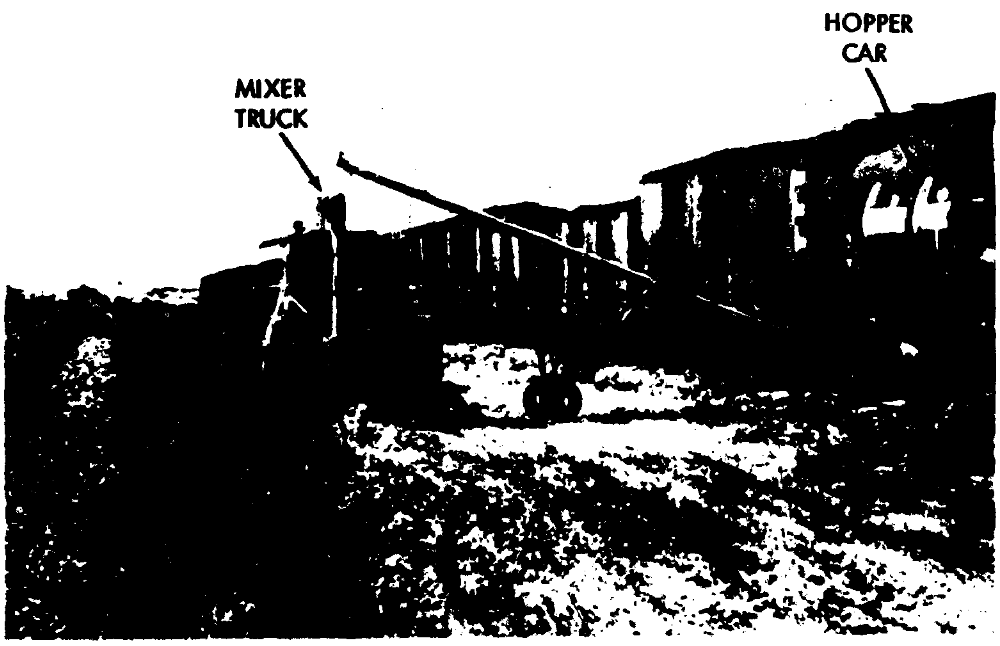


FIG. 3 AN/FO MIXER TRUCK TAKING ON AN FROM 70-TON HOPPER CAR AT SUFFIELD, ALBERTA, RAILROAD SIDING

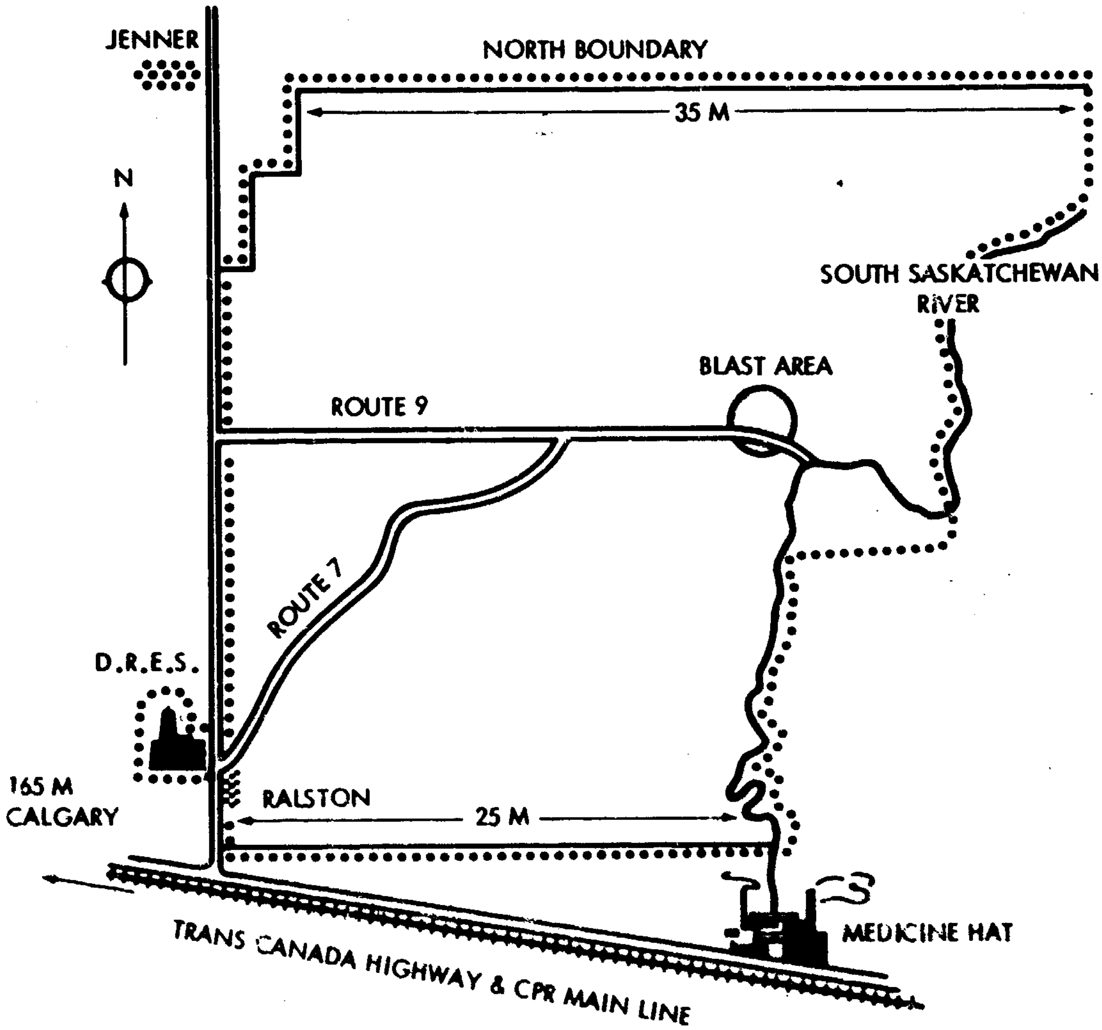


FIG. 4 THE DEFENCE RESEARCH ESTABLISHMENT, SUFFIELD, RALSTON, ALBERTA, CANADA

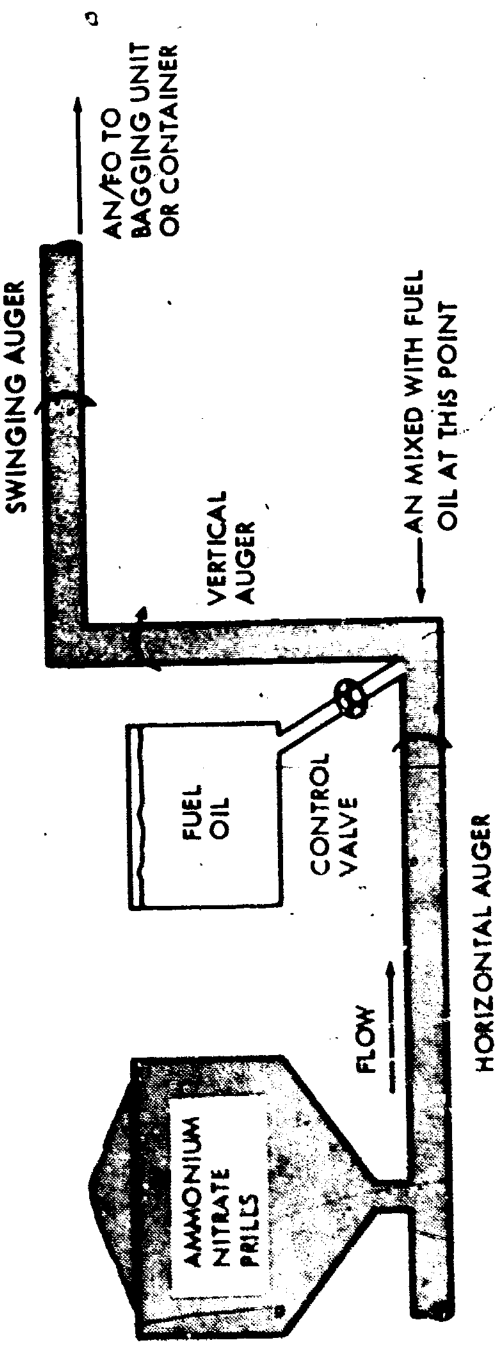


FIG. 5 AN/FO MIXER TRUCK FLOW DIAGRAM

FIG. 6 TRUCK SCALES USED FOR WEIGHING AN FO MIXER TRUCK, FULL AND EMPTY

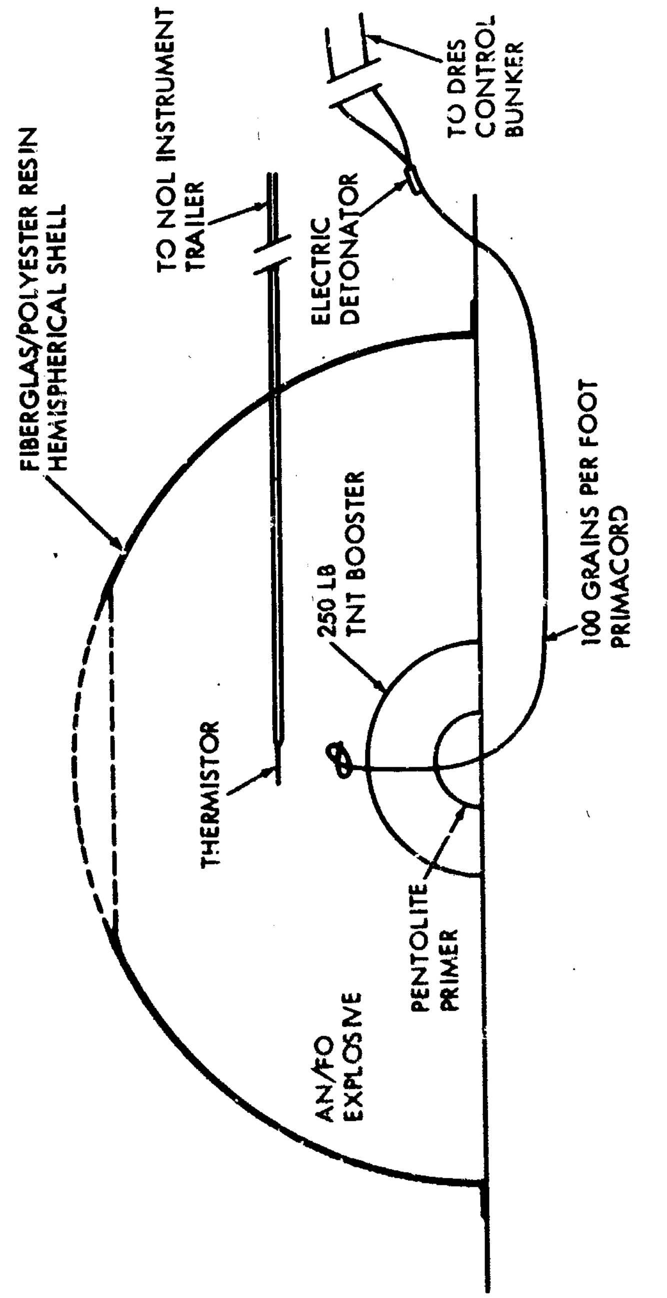


FIG. 7 SCHEMATIC ARRANGEMENT OF THE AN/FO CHARGES OF EVENTS II AND III

FIG. 8 LAYOUT OF GZ FOR EVENT I SHOWING 250 POUND TNT BOOSTER IN PLACE.
NOTE PRIMACORD EXTENDING BEYOND UPPER LEFT CORNER OF TARPAULIN.

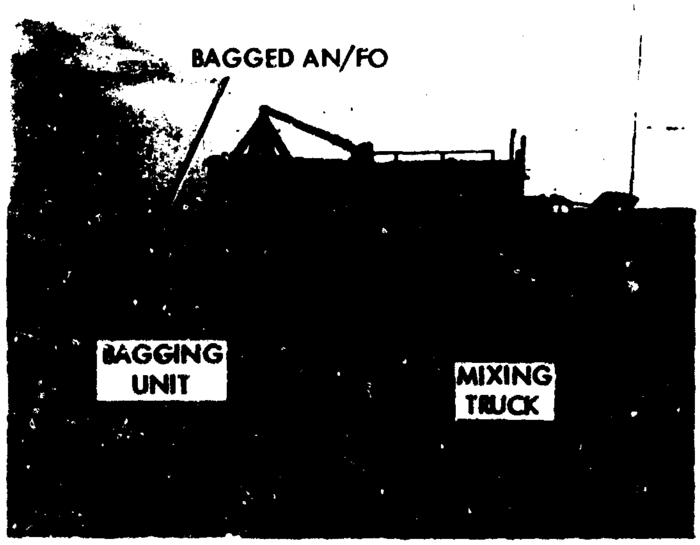


FIG. 9 ON-SITE AN/FO MIXING AND BAGGING OPERATION FOR EVENT I

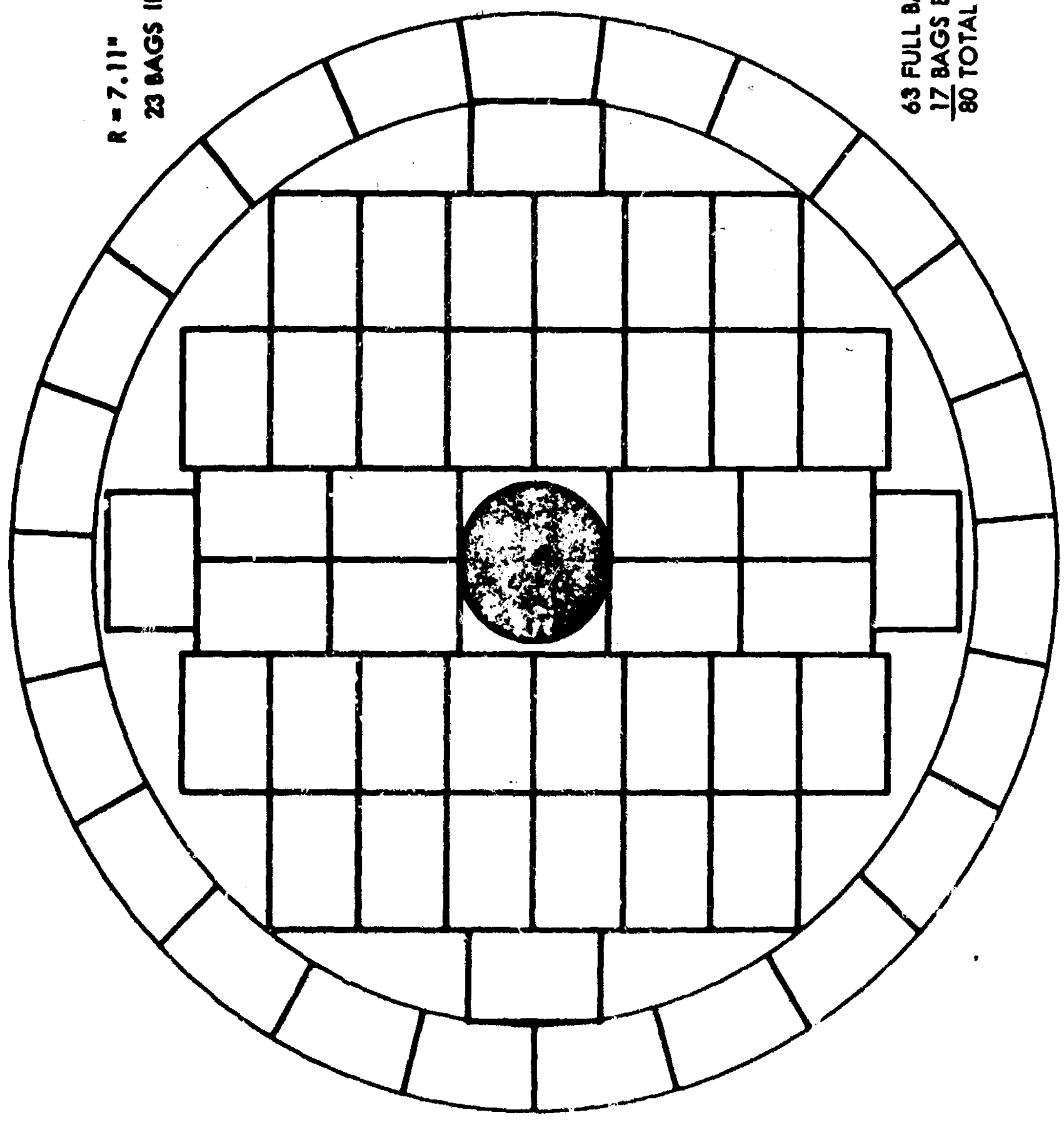


FIG. 10 EVENT 1, LAYER 1 & LAYER 2

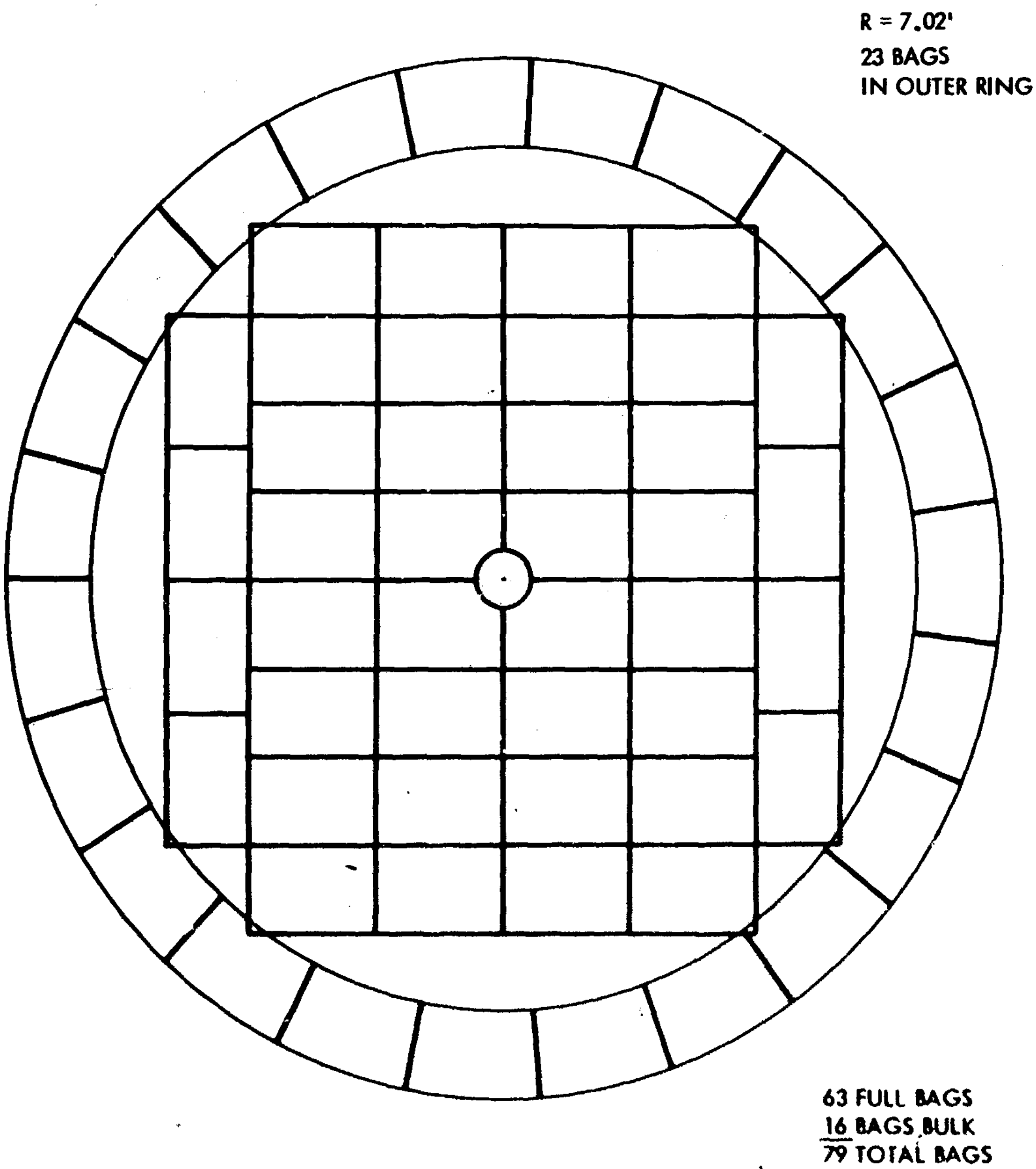


FIG. 11 EVENT I, LAYER 3

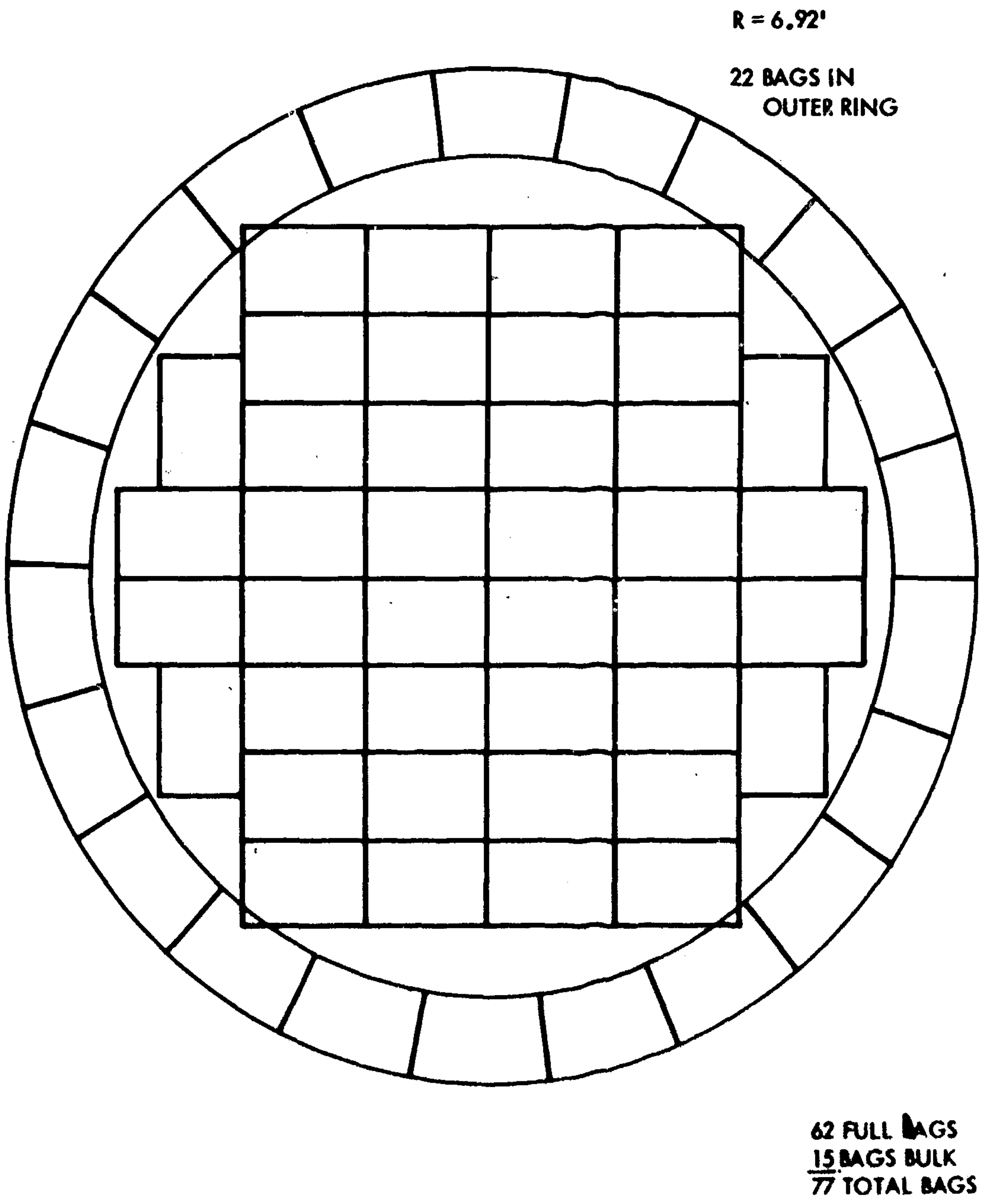


FIG. 12 EVENT I, LAYER 4

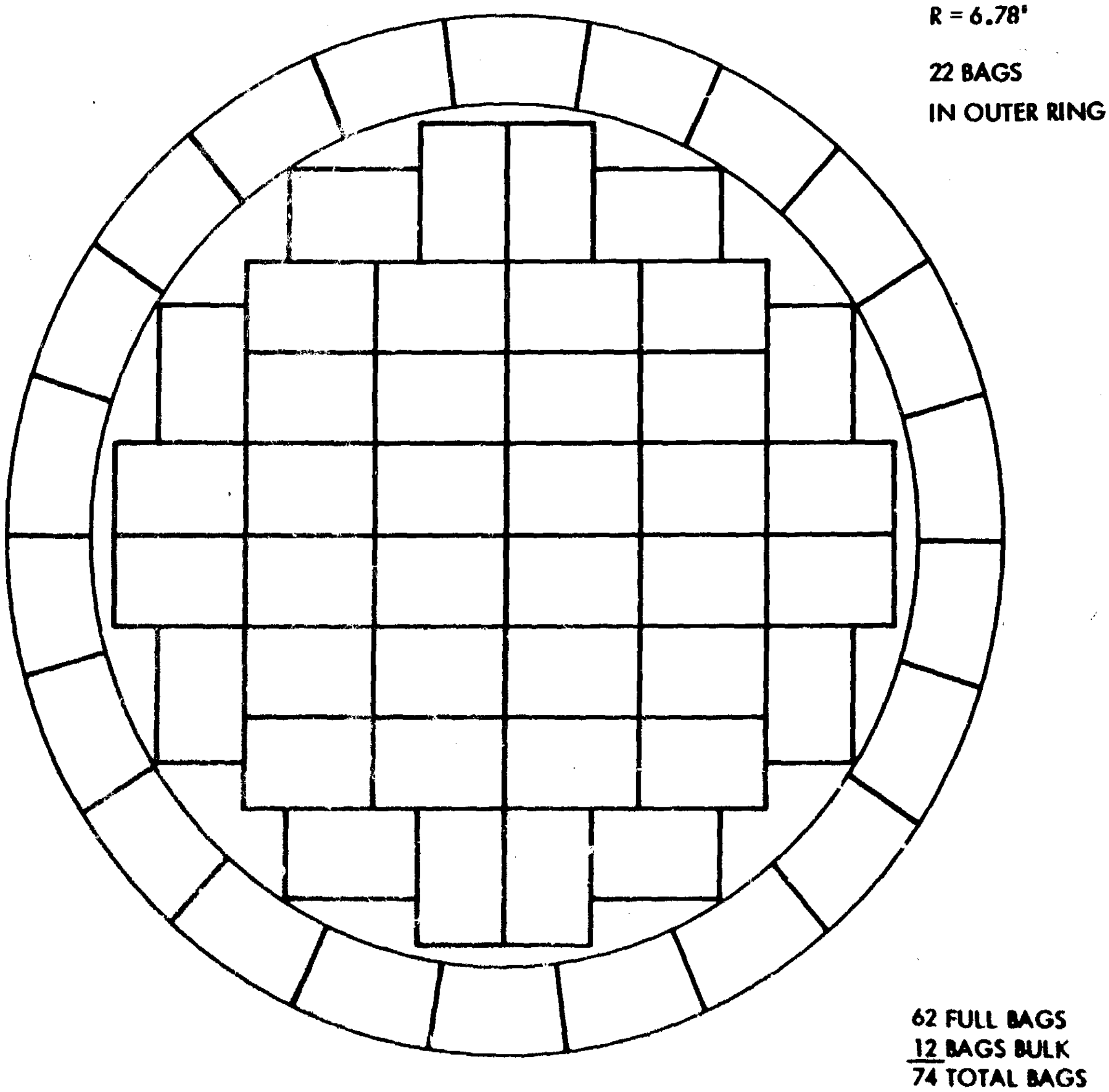


FIG. 13 EVENT I, LAYER 5

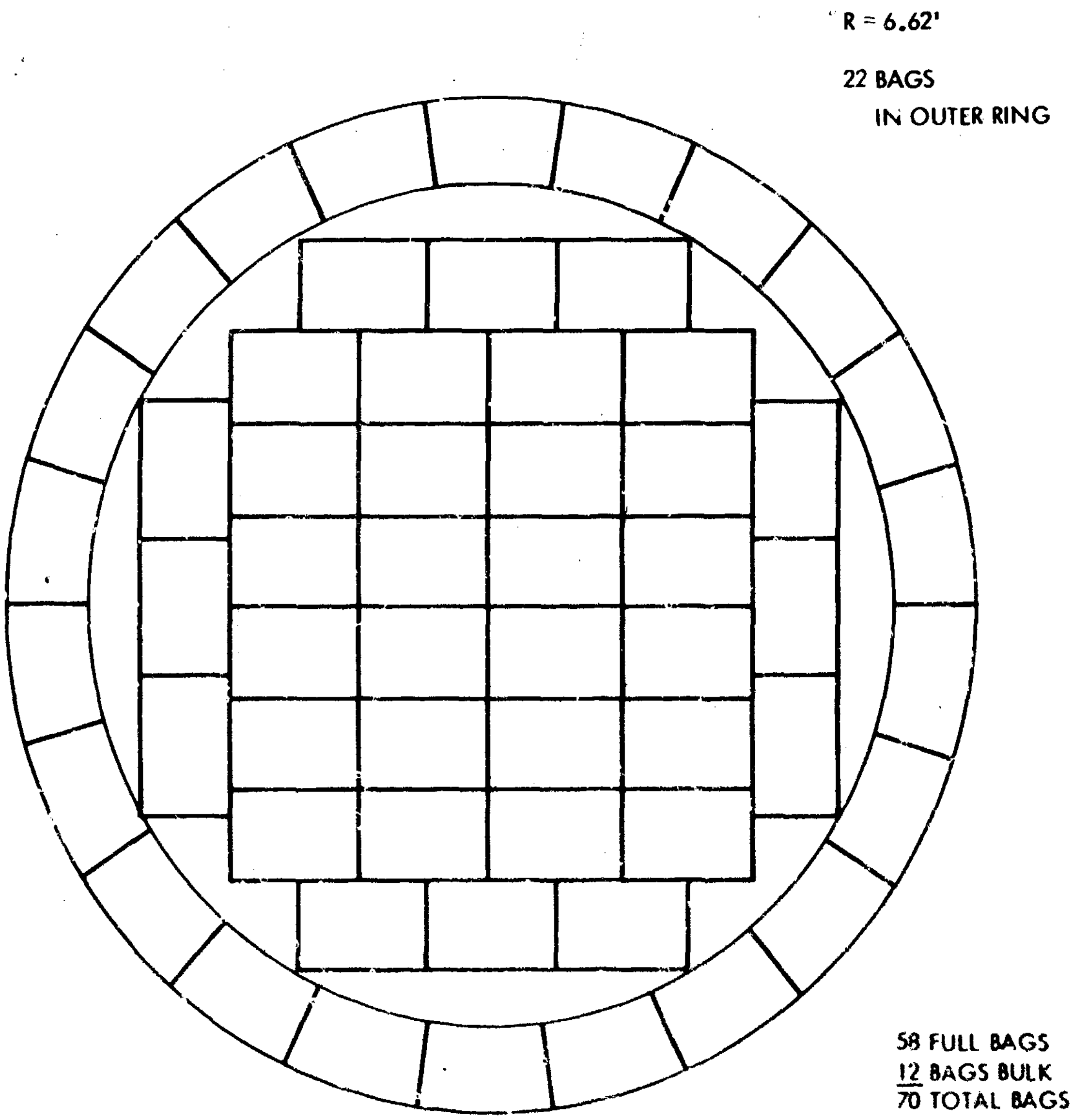
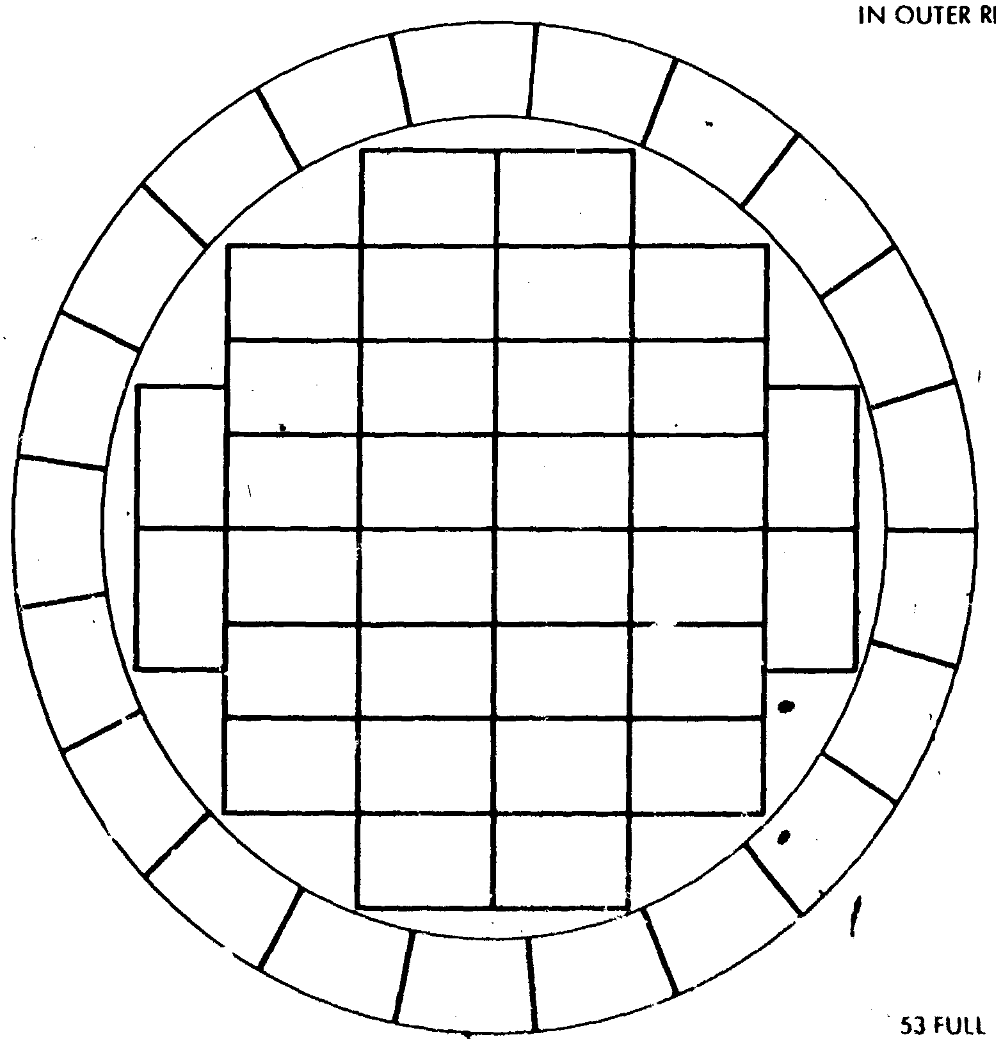


FIG. 14 EVENT I, LAYER 6

R = 6.40'
21 BAGS
IN OUTER RING



53 FULL BAGS
12 BAGS BULK
65 TOTAL BAGS

FIG. 15 EVENT I, LAYER 7

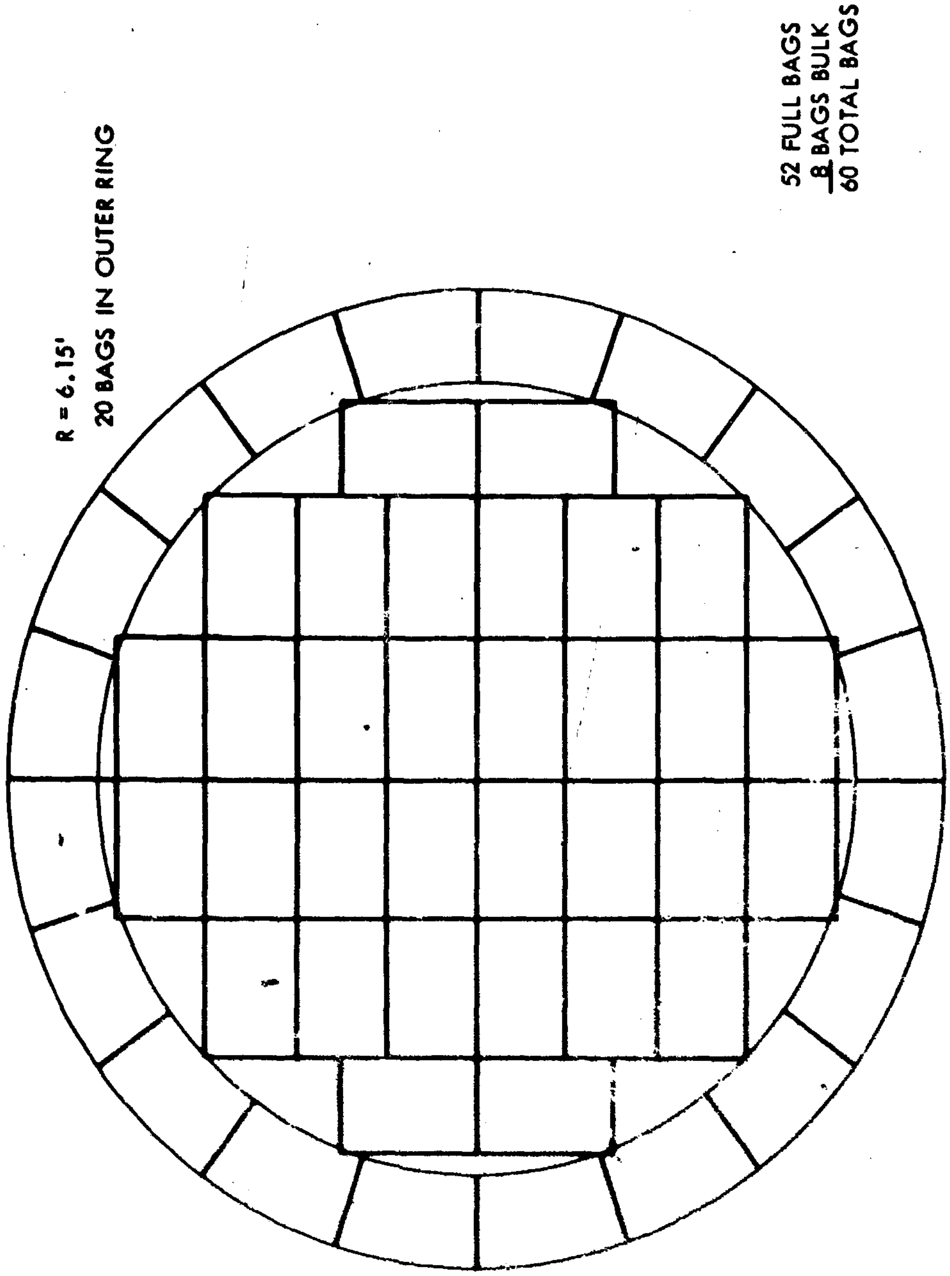


FIG. 16 EVENT I, LAYER 3

R = 5.83'
19 BAGS IN OUTER RING

45 FULL BAGS
10 BAGS BULK
55 TOTAL BAGS

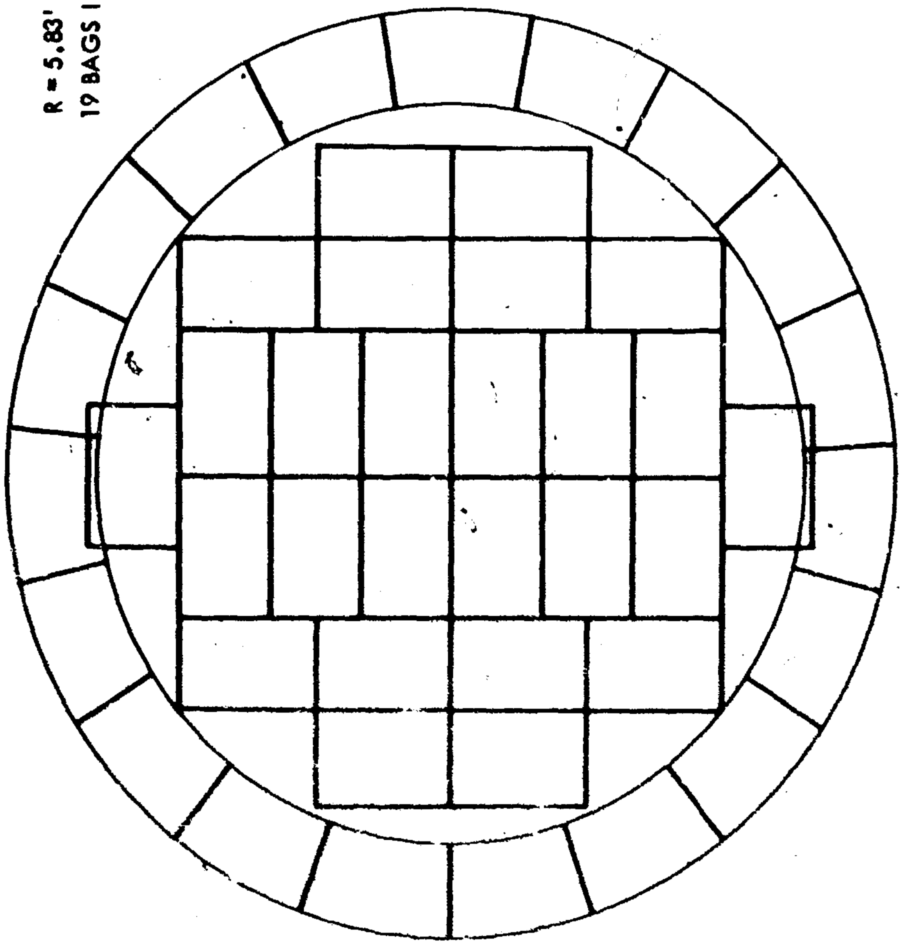


FIG. 17 EVENT 1, LAYER 9

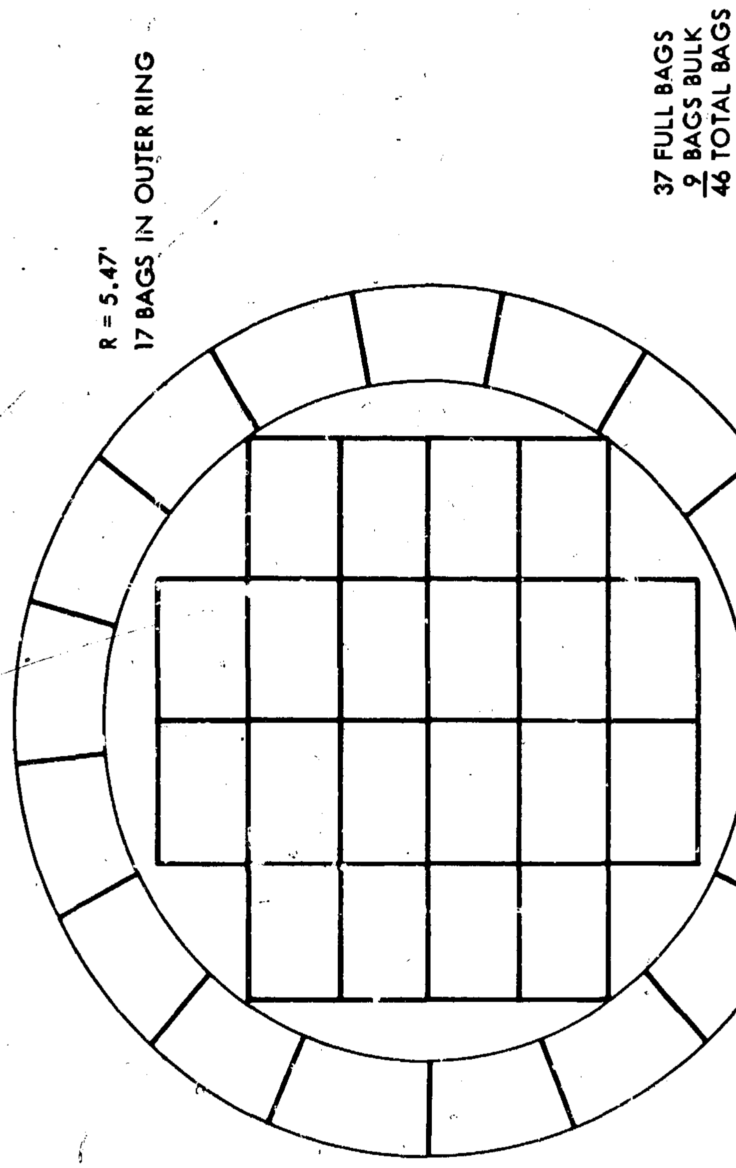


FIG. 18 EVENT I, LAYER 10

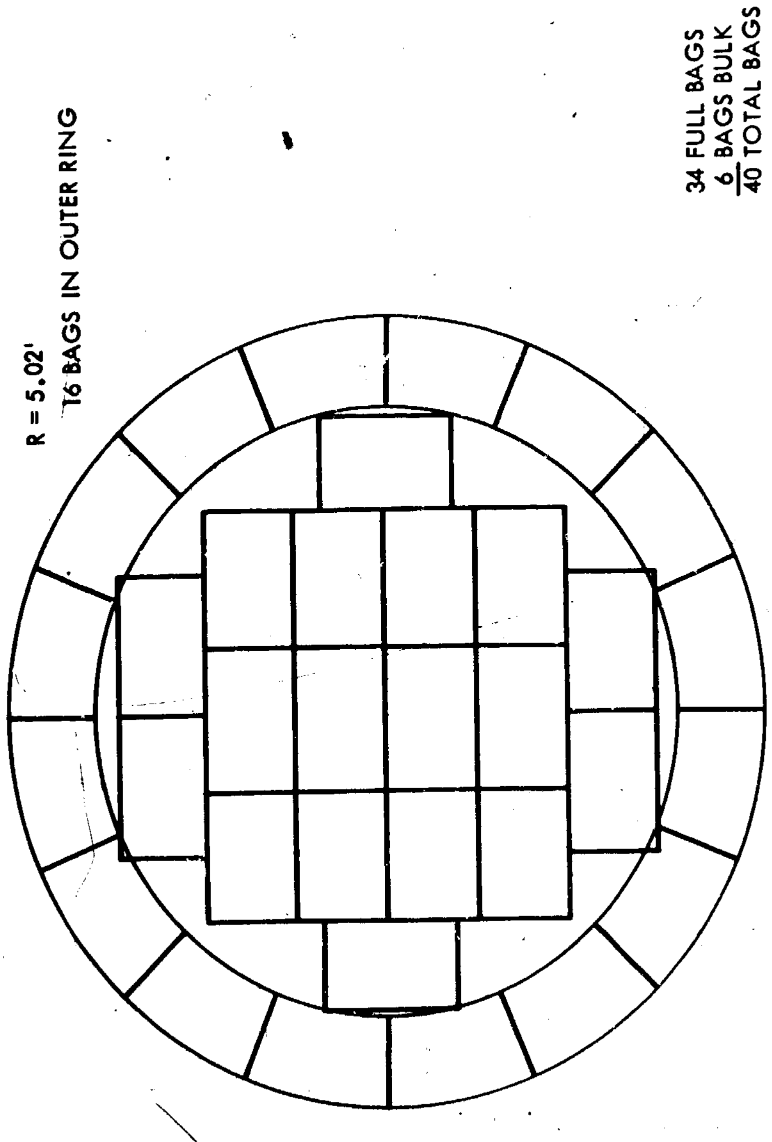


FIG. 19 EVENT I, LAYER II

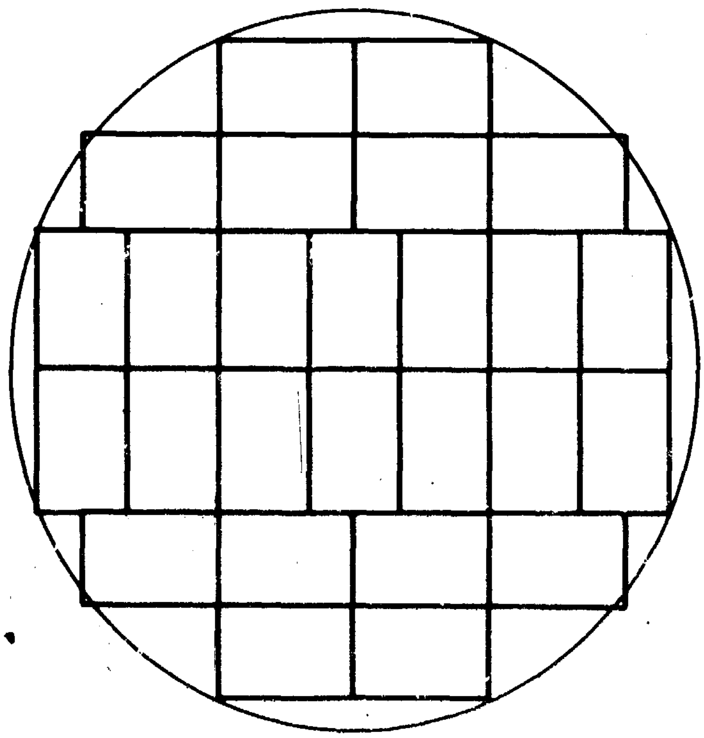
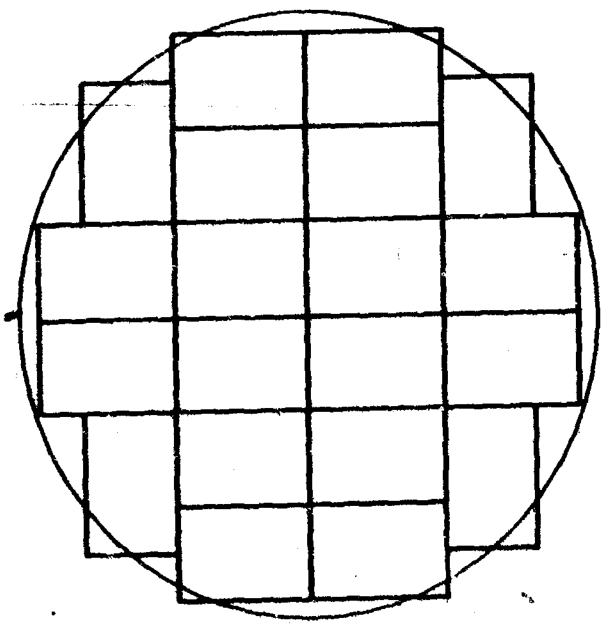


FIG. 20 EVENT I, LAYER 12

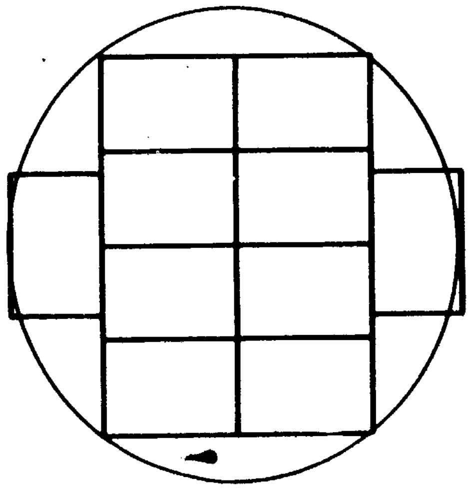
R = 3.83'



20 FULL BAGS
4 BAGS BULK
24 TOTAL BAGS

FIG. 21 EVENT I, LAYER 13

R = 2.95'



10 FULL BAGS
4 BAGS BULK
14 TOTAL BAGS

FIG. 22 EVENT I, LAYER 14

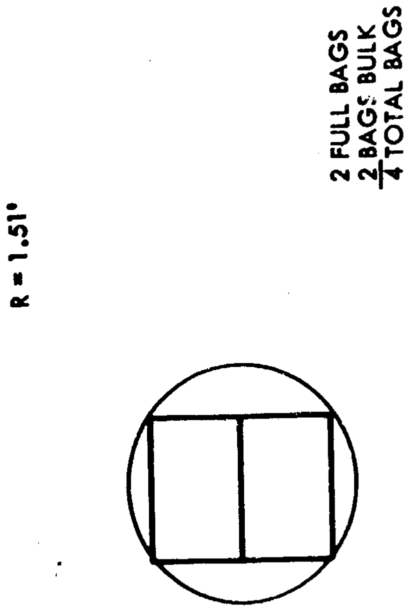


FIG. 23 EVENT I, LAYER 15

FIG. 24 EVENT 1, LAYER 2 PRIOR TO FILLING SPACES WITH LOOSE AN/FO

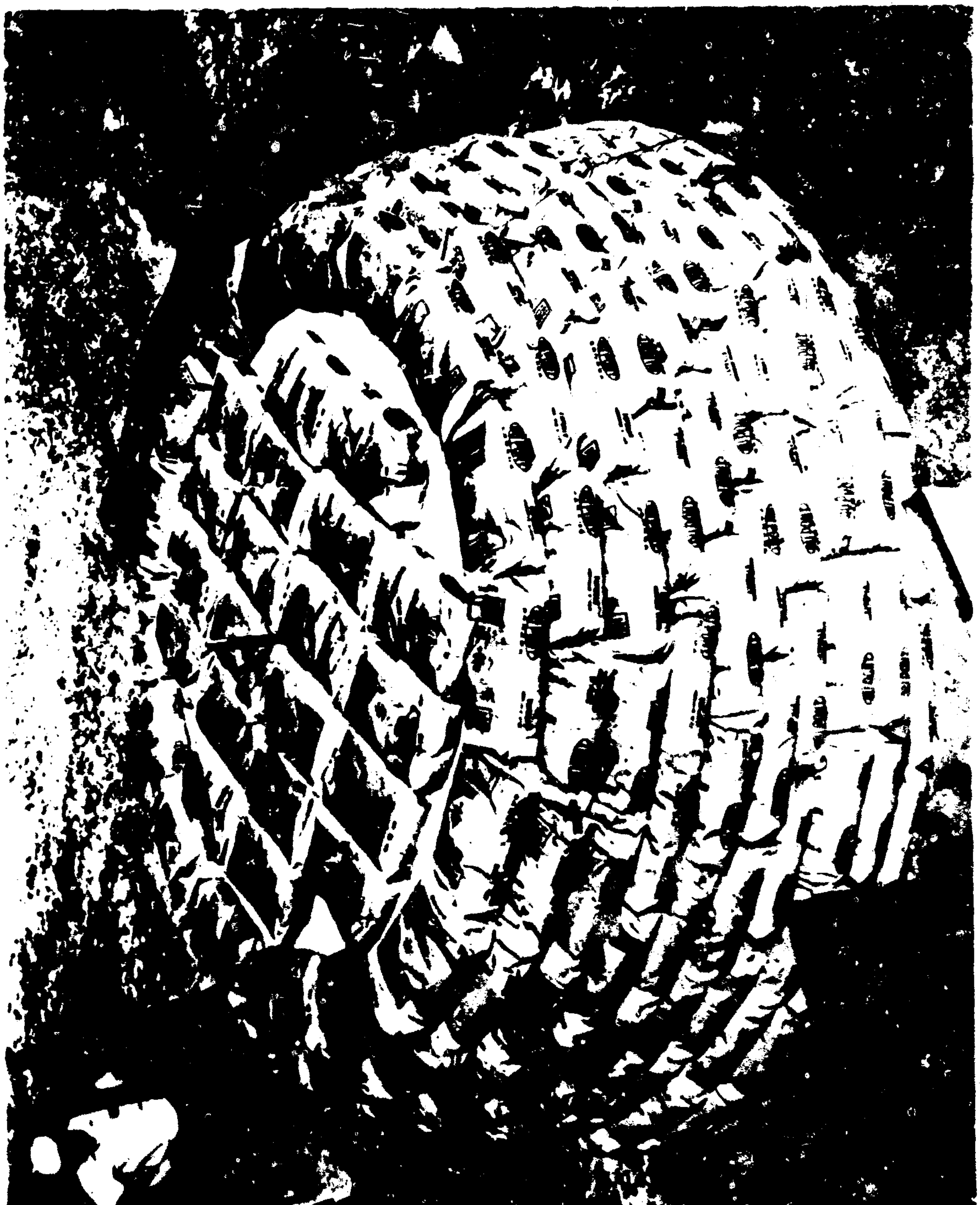


FIG. 25 EVENT I, LAYER 10 PRIOR TO FILLING SPACES WITH LOOSE AN/FO

FIG. 26 COMPLETED CHARGE FOR EVENT I. TOTAL WEIGHT: 20 TONS OF AN/FO.

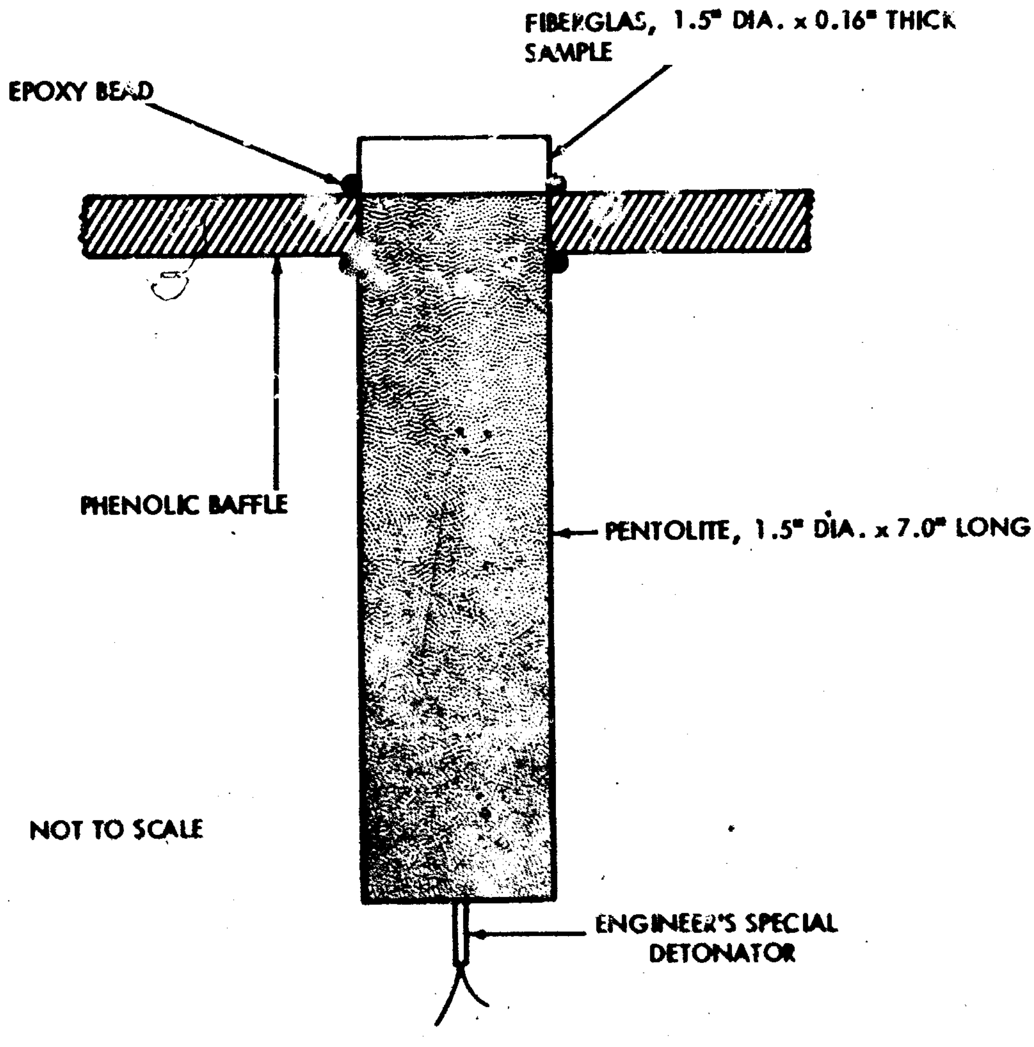


FIG. 27 EXPERIMENTAL ARRANGEMENT FOR EXPLOSIVE LOADING TEST ON FIBERGLAS

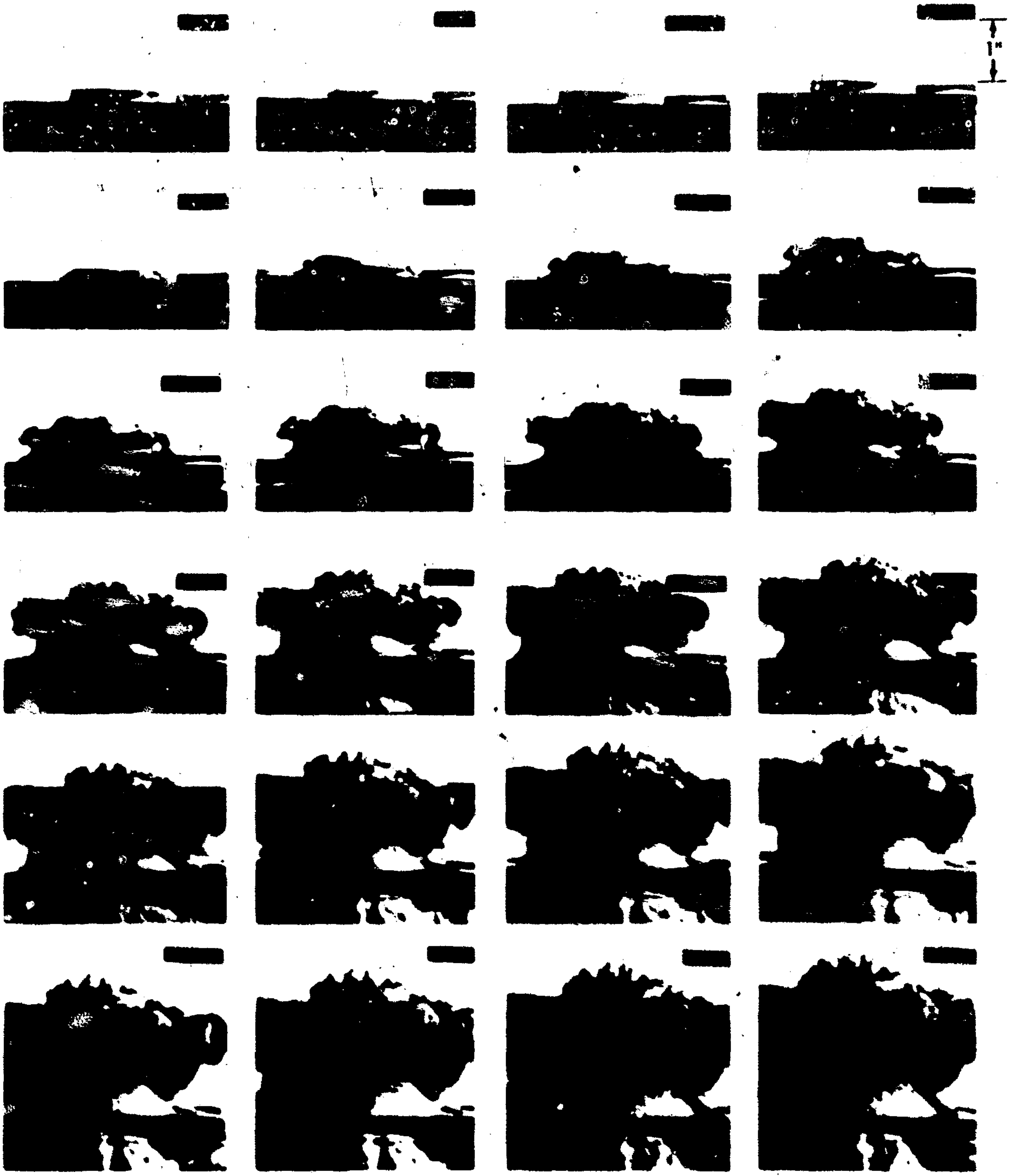


FIG. 28 FRAMING CAMERA SEQUENCE SHOWING BREAK-UP AND EVIDENCE OF BURNING OF FIBERGLAS LAMINATE

NOTE: TIME BETWEEN FRAMES 0.91 μSEC.

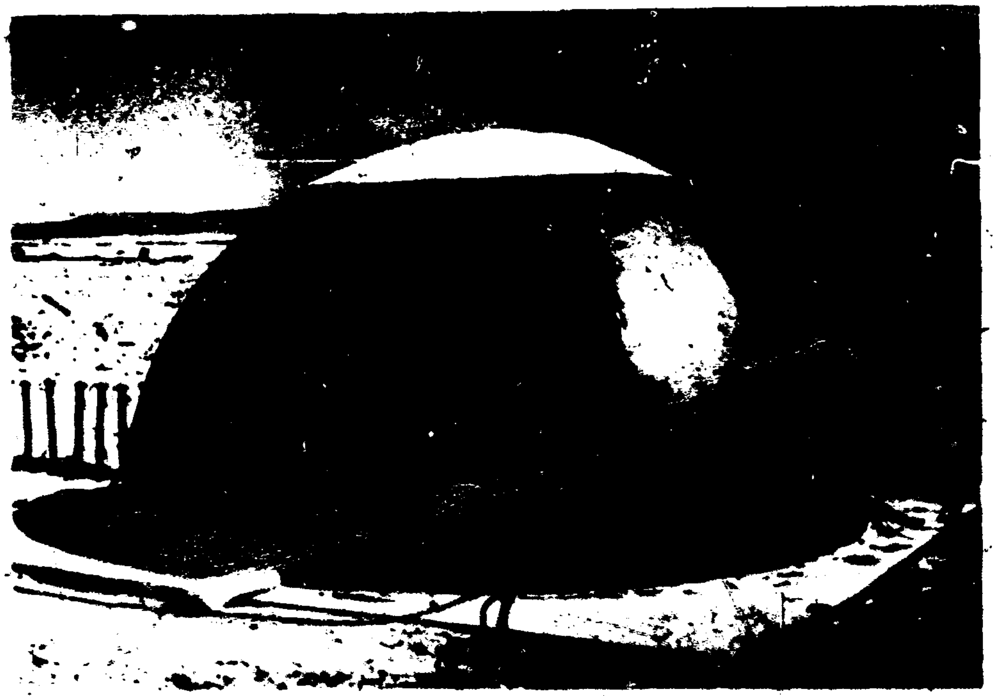


FIG. 29 AN/FO CHARGE FOR EVENT II. CONTAINS 18.8 TONS OF AN/FO.

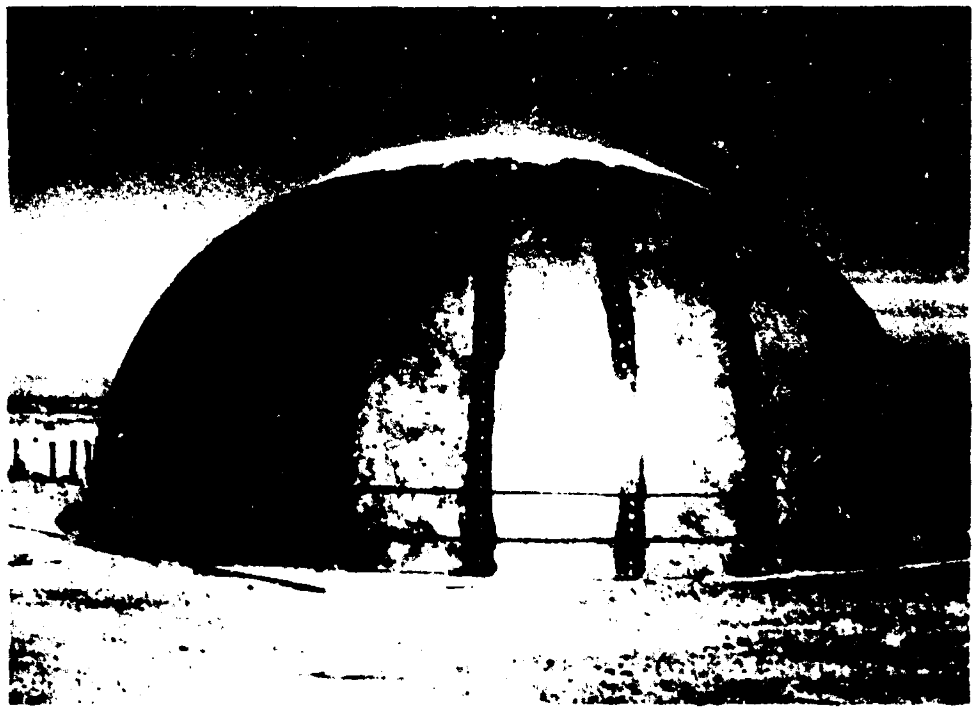


FIG. 30. AN/FO CHARGE FOR EVENT III. CONTAINS 100 TONS OF AN/FO.

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13. ABSTRACT

Two 20- ton and one 100-ton hemispherical AN/FO charges were detonated on the surface at the Defence Research Establishment, Suffield, Ralston, Alberta, Canada. The charges were all prepared with on-site mixing of the AN/FO over a 15 day period during August 1969. The first 20-ton charge was prepared from 800 fifty pound bags of AN/FO stacked in a hemispherical pile. The remaining charges were formed in thin hemispherical fiberglas shells. Each charge was initiated by a 250-pound booster.

AN/FO has been demonstrated to be a highly suitable explosion source for simulation of nuclear airblast.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Explosives Charge construction Ammonium Nitrate/Fuel Oil Physical properties Nuclear simulation						

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